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BACK PAIN AND ENDURANCE TRAINING OF BACK MUSCLES: JUSTIFICATION FOR FURTHER STUDY IN HELICOPTER PILOTS

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Dedicated with love and appreciation to

My wife, Lisa,

My son, Nick,

and

all those who assisted me in this endeavor

BACK PAIN AND ENDURANCE TRAINING OF BACK MUSCLES: JUSTIFICATION FOR FURTHER STUDY IN HELICOPTER PILOTS

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THESIS

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BACK PAIN AND ENDURANCE TRAINING OF BACK MUSCLES: JUSTIFICATION FOR FURTHER STUDY IN HELICOPTER PILOTS

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A qualitative literature review was performed to determine if endurance training of back musculature could be used as a primary preventive measure to decrease the incidence of back pain in helicopter air crews. Articles and other literature reporting the results of endurance training were selected for intensive review according to the following specific criteria:

1. The article described a prospective interventional study;
2. Back musculature endurance measurements for subjects were reported prior to the study commencement and at the conclusion of the study;
3. The length of the training program was specified;
4. A quantifiable measure of prevention was specified (e.g. reporting of back pain, work days lost, etc.).

Through this selection process only four studies were found that met the specified criteria. These studies were grouped by type (multidisciplinary; comprising exercise, education and, psychological counseling; exercise and education; or exercise only). The data from these studies were then placed into a database by study type. This database was then evaluated for trends and findings to determine if endurance training of the back musculature had an effect on the prevention of back pain.

We conclude that there is not enough literature to make a recommendation on the use of endurance training as a primary prevention modality for back pain. There are however, strong indicators supporting further evaluation of endurance training of back muscles as a primary preventive measure for back pain in helicopter air crew.

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History

Occupational back pain has been present since man began to work. One of the first documented episodes of occupational back pain is found in the Edwin Smith papyrus from the year 1500 BC (3). In 1705 AD Ramazinni described occupational back pain due to abnormal postures and movements in workers in *De Morbis Artificum* ("About Diseases of Workers") (54). Since his description, occupational back pain has been linked to abnormal postures including sitting (10, 25, 38).

Throughout the history of occupational back pain, multiple theories have been promulgated on its etiology. These theories encompass a full spectrum, from sprains, strains and weakness to trauma (3). Despite the abundant knowledge and literature on occupational back pain (except in the case of acute trauma, herniated disc or overt disease), the pathological causes of back pain have remained largely unknown and speculative. In fact, the cause of most cases of occupational back pain remain undiagnosed (3, 19).

As stated by Ehni in his presidential address to The International Society for the Study of the Lumbar Spinal in 1980, "it is clear from the literature that back pain is a multifaceted illness that encompasses both physical, psychological and social aspects in man" (19). Treatments for back pain have ranged from conservative resting and soaks to blistering, surgery and, most recently, multidisciplinary programs that include both psychological, educational, and physical elements (2, 3, 7).

Back pain in the United States is now one of the major causes of lost work days, accounting for 27% of workdays lost due to nonfatal illness or injury. It is also the number-one cause of work-related disability claims (33). It has been estimated that 14 billion dollars were spent on treatment and compensation of occupational back pain in 1976. By 1983, the price of back pain was estimated at 25.25 billion dollars (57). The National Institute of Occupational Safety and Health estimates that the total cost of back pain in 1990 was between 50 and 100 billion dollars (33).

Occupational back pain has been well documented in the military (3, 23, 24, 50, 58). During the First World War the British military became interested in back pain when large numbers of recruits "broke down" with back pain despite being screened prior to enlistment. Special army training battalions were formed to train these men. Through this training the army demonstrated that 80% of new recruits suffering from back pain could be rehabilitated and returned to duty (3).

Although it is now assumed and accepted that exercise programs play a significant role in back pain rehabilitation and prevention, it is not clear whether or not strength, endurance training, or mobility training are more important in preventing low back pain (36). There is however, abundant amount of literature on strength training and strength measurements in the prevention of back pain (1, 5, 6, 30, 37, 39, 44, 45). While most studies support strength training and strength measurements as indicators of back pain rehabilitation and prevention, a few have found no association between strength and prevention or rehabilitation of back pain (5, 37, 45). Some investigators have

demonstrated that back musculature endurance measurements are good predictors of future occupational back pain sufferers (8, 45).

The purpose of this study is to review the literature systematically to determine if available published evidence is sufficient to recommend endurance training of back musculature as a preventive measure for helicopter back pain. Based on this review, further studies will be recommended to evaluate the effectiveness of back musculature training in helicopter back pain.

Helicopter Back Pain

Since the First World War many military researchers have looked at occupational back pain in unique military environments. One of the most recent military occupations to be linked to back pain has been the aerospace crew member occupation. Multiple articles have documented the increased prevalence of occupational back pain among all pilots (23, 24, 42, 49, 50, 53, 55, 56).

For the purpose of this study, helicopter back pain may be defined as back pain that is associated with performing flying duties during a helicopter flight. It may be transient and resolve with termination of the flight, or it may become persistent and lead to chronic back pain which is noticeably worse during helicopter operations (10, 20, 50).

A study of 802 pilots performed by the United States military in 1986 established that helicopter pilots suffer from occupational back pain at a rate three times higher than fighter pilots and six times greater than tanker pilots (23). Helicopter pilots have one of the highest overall rates of occupational back pain documented (23, 24, 42, 49, 50, 53, 55, 56). Table 1 lists several studies performed over the past twenty years which report estimates of helicopter back pain prevalence. Despite this consistently high prevalence of occupational back pain, few studies have been performed to evaluate cause or effect of back pain in helicopter pilots or ways to decrease this elevated prevalence.

Table 1: List of Helicopter Related Back Pain Studies with Prevalence of Disease

Primary Investigator	Year	Prevalence
Silosberg	1962	87.5
Schulte-Wintrop	1978	40.0
Malik	1981	84.0
Singh	1983	100.0
Shanahan	1984	72.8
Froom	1986	57.6
Sheard	1996	82.0

In 1991 the Canadian forces revealed that back pain is the second leading cause of flight restrictions (58). United States Army studies have demonstrate that occupational back pain in helicopter pilots has a significant impact on flying missions. This effect encompasses decreased flight safety from pilots rushing through missions and, pilots refusing to fly missions due to back pain (10, 50). A study of helicopter pilot back pain, performed for the United States Army has found that 28.4% of pilots suffering from back pain admitted rushing through missions and, 7.5% refused to fly missions (50). Although no data are available on the number of missions lost or disability among helicopter pilots, it is clear from these studies that occupational back pain in helicopter pilots effects their capability to perform missions in a relatively safe and healthy environment.

Occupational and physical factors placing all workers at risk for occupational back pain have been identified in the general work force (5, 22, 34). Helicopter pilots are effected by these factors, some of which have been specifically implicated as a cause of back pain (49, 50, 55). Table 2 lists both personal and job-related risk factors for occupational back pain in helicopter pilots. These factors have been discussed in the helicopter back pain literature as well as the general occupational back pain literature.

Table 2: Risk Factors Associated with Occupational Back Pain in Helicopter Pilots

Personal	Job
Age	Prolonged static sitting
Physical fitness	Vibration
Medical history	Heavy physical work
Psychological factors	Flying time of the current mission
Structural abnormalities	Total flying hours in the pilots career
Social factors (smoking, alcohol, athletics, etc.)	Twisting and bending
	Environmental temperature
	Accidents/Traumatic events

To date, the research on cause of occupational back pain in helicopter pilots has centered on the sitting posture and vibrational factors. Shanahan and Pope looked at the vibrational factor in two separate studies (46, 51). Both researchers ascertained that vibration is not as significant a risk factor as previously believed. Each demonstrated that the static sitting posture created by current helicopter seats, excluding vibration, is a major cause of back pain. From these data, both authors speculated that seat design is the major contributing factor for back pain in this population.

United States Army helicopter pilots have reported that they are capable of delaying the onset of back pain in flight if they use some type of lumbar support (52). Canadian and British forces have evaluated the ergonomic effects of lumbar supports in pilots with chronic back pain (47, 49). The Canadian study found that a 40% decrease in back pain could be achieved among pilots experiencing chronic back pain when they were fitted with molded fiberglass lumbar supports (47).

Review of the helicopter back pain literature has revealed: 1) that other identified risk factors, listed in Table 2, have not been evaluated to determine their impact on this problem; and 2) prevention measures aimed at these risk factors have not been evaluated.

Materials and Methods

To evaluate the evidence that endurance training of the low back musculature will decrease the prevalence or prevent the onset of back pain, a qualitative review of the literature relating to endurance training of the back musculature as a preventive measure for back pain was performed. Articles for this study were acquired through a search of both MEDLINE and Health databases covering all years available. A protocol that listed all relevant articles was applied to both databases. Protocol selection criteria are listed in Table 3. The list of references that resulted from this search were then copied to disk and transferred to a ProCite 3 reference management database. This database was then evaluated and duplicate articles were removed. The remaining articles were screened for the following study inclusion criteria by the author:

1. The study described in the article was a prospective interventional study;
2. Back musculature endurance measurements for subjects were reported prior to the study commencement and at conclusion of the study;
3. The length of the training program was specified;
4. A quantifiable measure of prevention was specified (e.g., reporting of back pain, work days lost, etc.).

Only four articles met the criteria, including two that reported findings of a single study.

Due to the low number of articles found meeting the inclusion criteria, the procedure was repeated removing protocol steps 27 and 28 in an attempt to locate more articles that had not been listed under the initial protocol. In this much broader search of the literature, 1122 articles were found in both databases. After entering the articles into ProCite 3 and removing duplicates, 745 articles remained. Inclusion assessment criteria were then applied to all articles that could be found, and one more article meeting the study inclusion criteria was qualified in this broader search of the literature.

The five articles, representing four studies, were then grouped by study type (Table 4) and entered into a database. This database (Tables 5 and 6), was used to evaluate data reported in the selected articles for trends in outcome measurements to determine: 1) if endurance training of the back musculature had an effect on the prevention of back pain; 2) which endurance exercise protocol had the best result; and 3) the optimal time required to achieve these results.

Table 3: Protocol for the Selection of Publications on Back Pain and Endurance Training

Set	Search
1	back pain or lumbago or low back pain
2	physical therapy
3	exercise therapy
4	motion therapy, continuous passive
5	occupational therapy
6	rehabilitation
7	physical medicine
8	primary prevention
9	aerospace medicine
10	health education
11	patient education
12	sports medicine
13	occupational medicine
14	self care
15	physical endurance
16	exercise tolerance
17	public health
18	activities of daily living
19	preventive medicine
20	2 or 3 or 4 or 5 or 6 or 7 or 8 or 9 or 10 or 11 or 12 or 13 or 14 or 15 or 16 or 17 or 18 or 19
21	1 and 20
22	limit 21 to review
23	21 not 22
24	limit 23 to letter
25	23 not 24
26	limit 25 to English language
27	prospective study or interventional study or clinical trial
28	26 and 27

Results

Despite the use of a very broad search protocol, only four studies were found that evaluated endurance of the back musculature and its relationship to preventing or rehabilitating patients suffering from back pain. Table 4 lists those studies selected for evaluation based upon the predefined study inclusion criteria.

Studies I and II were based on multidisciplinary protocols. These studies included psychological and educational training with an intensive exercise program. Study III was presented in two separate articles. The first article covered the initial assessment of physical parameters and the follow-up article assessed preventive parameters. Study III evaluated graded physical exercise based on the patients' functional assessment and education. Study IV evaluated only physical exercise in the intensive and moderate categories. In three of the studies (I, II, III), the treatment groups were compared to the "usual treatment," with the treatment protocol left largely to the discretion of the control group patients' treating physicians. Study III was the only study that clearly described the control group treatment protocol. Study I was the only study to stratify data by gender. While none of the studies stratified the data by age.

Table 4: Studies Meeting Inclusion Criteria

#	Primary Author	Title	Program type
I	Alaranta	Intensive Physical and Psychosocial Training Program for Patients With Chronic Low Back Pain: A Controlled Clinical Trial	Multidisciplinary
II	Bendix	Multidisciplinary Intensive Treatment for Chronic Low Back Pain: A Randomized Prospective Study	Multidisciplinary
III	Lindstrom	The Effect of Graded Activity on Patients With Subacute Low Back Pain: A Randomized Prospective Study With An Operant-Conditioning Behavioral Approach and Mobility, Strength, and Fitness After a Graded Activity Program for Patients with Subacute Low Back Pain: A Randomized Prospective Clinical Study With a Behavioral Therapy Approach	Physical exercise and educational
IV	Manniche	Clinical Trial of Intensive Muscle Training for Chronic Low Back Pain	Physical exercise

Multidisciplinary = Physical exercise, educational and psychological counseling

Table 5: Reported Objective Measurements of Improvement in Response to a Back Endurance Training Program (Study Number from Table 4; P Values by Parameter Measured)

Study	I				II	III			IV		
Type	Intensive physical & psychological					Graded Activity & Education			Physical Only		
F/U	3 Mo		1 Yr		4 Mo	Pre Post	1 Yr	1 Yr	3 Mo		
	Male	Female	Male	Female				treatment group change	A conservative treatment	B intensive treatment	C moderate treatment
Back endurance	0.05	0.001	NS	0.001	<0.001	<0.01	<0.01	<0.001	NS	0.02	0.001
Medical service use	n.a.	n.a.	67% decrease at 1 yr.		<0.001	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Return to work rate	n.a.	n.a.	n.a.	n.a.	<0.001	0.001	n.a.	n.a.	n.a.	n.a.	n.a.
# of subjects returned to work	n.a.	n.a.	n.a.	n.a.	<0.001	0.03	n.a.	n.a.	n.a.	n.a.	n.a.
Sick leave	41% decrease treatment at 1 yr. 37% decrease in control at 1 yr.				0.02	n.a.	n.a.	0.04	n.a.	n.a.	n.a.

NS = $p > 0.05$
P values are for comparisons of the treatment group and control group except in the Study III 1 year follow-up indicated by "treatment group change".

Table 5: Reported Objective Measurements of Improvement in Response to a Back Endurance Training Program (continued)
(Study Number from Table 4; P Values by Parameter Measured)

Study	I				II	III			IV		
Type	Intensive physical & psychological					Graded Activity & Education			Physical		
F/U	3 Mo		1 Yr		4 Mo	Pre Post	1 Yr	1 Yr	3 Mo		
	Male	Female	Male	Female				treatment group change	A conservative treatment	B intensive treatment	C moderate treatment
Impairment	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	NS	0.001	0.001
Schobers' test	n.a.	n.a.	n.a.	n.a.	n.a.	<0.01	<0.01	<0.001	NS	0.001	0.001
WHO occupational handicap	n.a.	n.a.	0.019	NS	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Mobility											
-range	NS	NS	NS	NS	n.a.	0.001	0.01	0.001	n.a.	n.a.	n.a.
-back	0.001	0.001	0.01	0.01	n.a.	0.001	0.01	NS	n.a.	n.a.	n.a.
-side	0.001	0.001	0.001	0.001	n.a.	NS	0.01	NS	n.a.	n.a.	n.a.
-rotation	n.a.	n.a.	n.a.	n.a.	n.a.	0.01	0.01	NS	n.a.	n.a.	n.a.

NS = P > 0.05
P values are for comparisons of the treatment group and control group except in the Study III 1 year follow-up indicated by "treatment group change".

Table 6: Reported Subjective Measurements of Improvement in Response to a Back Endurance Training Program (Study Number from Table 4; P Values by Parameter Measured)

Study	I				II	III			IV		
Type	Intensive physical & psychological					Graded Activity & Education			Physical		
F/U	3 Mo		1 Yr		4 Mo	Pre Post	1 Yr	1 Yr	3 Mo		
	Male	Female	Male	Female				treatment group change	A conservative treatment	B intensive treatment	C moderate treatment
Subjective performance	0.017	0.006	0.036	NS	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Subjective pain	n.a.	n.a.	n.a.	n.a.	0.05	n.a.	n.a.	n.a.	NS	NS	0.001
Subjective activity function disability	n.a.	n.a.	n.a.	n.a.	<0.001	n.a.	n.a.	n.a.	NS	0.001	0.001
Million index	0.001		0.001		n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Psychological factors	NS	NS	NS	NS	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.

NS = $p > 0.05$
P values are for comparisons of treatment and control groups except in the Study III 1 year follow-up group indicated by “treatment group change” .

Looking at the data derived from these four studies (Tables 5 and 6), one immediately notices that the parameters measured vary widely among the studies.

These data are grouped into two categories in Table 7 Which list all parameters that were evaluated in more than one study. Category 1 list the parameters evaluated for improvement with the number of studies supporting or not supporting the improvement. Each of the parameters in this category received either complete or incomplete support. Category two are those parameters which had at least one study that did not report a statistical improvement in the measured parameter.

All studies demonstrated a significant increase in back endurance when compared to the control group ($P \leq 0.05$) at the initial follow-up exam. Study I however, found that this improvement became non-significant at the one-year follow-up in males but remained very significant in females ($P = 0.001$). Study III found endurance to be significantly improved in the treatment group when compared to the control group and also demonstrated that back endurance in the treatment group improved statistically from their base line evaluation.

In the two studies that considered return to work, both demonstrated a significant increase in the rate at which workers in the treatment group returned to work. Both studies also demonstrated a significant increase in the number of people returning to work by the first follow-up.

Table 7: Parameters Measured in Multiple Studies

Category 1: Parameters with complete support for improvement			Category 2: Parameters with mixed support for improvement		
Parameter	Support Y/N	Number Studies	Parameter	Pos. Studies	Neg. Studies
Back endurance increase	Y	4	Sick leave	2	1*
Medical service use decrease	Y	2	Mobility	1	1**
Return to work rate	Y	2			
# Return to work	Y	2			
Schobers' test	Y	2			
Subjective pain improvement	Y	2			
Subjective activity, function, disability improvement	Y	2			

* Study found both control group and treatment group decreased sick days by 37 and 41%, respectively.
** No improvement over base line at 1 year follow up. Significant improvement over control group at 1 year, P = .01

Two studies evaluated medical service use. While Study I and Study II reported a decrease in use, only Study II reported this as a statistical finding. Study II reported a P value of 0.001. Study I listed a percentage difference (67%) at the one-year follow-up.

All studies that evaluated patients' subjective improvement in symptoms, function, activity and, disability, demonstrated a statistically significant improvement over their control groups. Of note, the authors of Study III reported no statistical improvement in the pain category when comparing their intense exercise group and control. However, they did report a statistical improvement with their moderate exercise group.

Forward flexion of the spine was evaluated in studies III and IV using Schobers' test. Both studies determined that there was a significant improvement at the initial follow-up. Study III also demonstrated that this improvement could be found at the one-year follow-up.

Only two parameters, sick leave and mobility, were found to have conflicting data. Studies II and III both reported a significant decrease in sick leave usage. Study I reported a non-statistical difference between the treatment and control groups. However, Study I did find a decrease the number of sick days in both control groups, which received the traditional inpatient care in Finland, and the treatment group. In the treatment group, the average number of sick days fell from 57.8 days to 33.9 days per year. In the control group, the average number of sick days fell from 58.5 to 36.9. Although there was no statistical difference between the groups, it appears there is a

significant difference in the pre and post sick day parameter measurement within each group receiving treatment.

Mobility measurements other than Schobers' test, were performed in Studies I and III. Study I reported significant changes in side bending and rotation, but not back extension. It also found no significant inter-group differences. Study III reported no significant change in these parameters when measuring within the treatment group. However, they did find a significant change at the one-year follow-up between the control and treatment groups.

A few findings were supported by only one study. Study IV found a significant decrease in impairment ratings. Study I found a significant improvement in the Million index, which is a subjective scale based on the patients' perception of his or her disability and pain. Study I also reported no significant change in several psychological factors evaluated (anxiety, socialization, social desirability and, adjustment).

Discussion

Article Selection

One might ask if observer bias played a part in the low number of papers selected for this study. Although observer bias may have potentially contributed to this low number of articles, the selection of inclusion criteria prior to the study and application of these predefined criteria reduced the importance that observer bias may have played.

Endurance is defined by *Webster's New Collegiate Dictionary* as "the ability to withstand hardship, adversity or stress". This definition clearly implies that there is a time component to the measurement of endurance. Previous studies evaluating back endurance as a predictor of back pain have measured endurance by timing a specific exercise or counting exercise repetition number (8, 9, 36, 37). Applying the requirement that a measurement of endurance must have a time component or repetition measurement also decreased the chance of observer bias in the selection of articles.

All articles in this study measured endurance by having study subjects hyper-extend their backs while in the prone position. Although one may wonder how the measurements of endurance might be affected by the subject's desire to perform the test, this method of measuring endurance has been evaluated by other research groups and found to be an accurate and reproducible measurement of endurance (5).

Data

Due to the low number of studies measuring each parameter, one can not develop absolute conclusions or spot trends. However, an indication for the support of endurance training as a tool in the rehabilitation and prevention of back pain can be identified.

From Table 7 one can see that all parameters measured except for sick leave and mobility, improved statistically in all the articles measuring these parameters. Even the two parameters that did not have complete support showed improvement when the data were evaluated and the mechanism of comparison was examined. Despite this indication it is impossible to conclude that back endurance training is the key to back pain prevention due to the low number of articles in this study.

Only study IV evaluated a program exclusively dedicated to back endurance exercises. Each of the other studies evaluated a program that had multiple components. One must therefore ask if the endurance training accounted for the improvements or if some other component of these multidisciplinary programs was involved in the overall effect.

Prevention

Few studies on the use of exercise as a primary prevention tool for back pain exist (24). In the military aerospace medical field, research in the area of primary prevention of occupational back pain is limited and usually centers on preemployment screening and ergonomic engineering design. In contrast, research on the prevention, treatment and rehabilitation of occupational back pain is common.

Preemployment screening, although controversial in the civilian world, does occur in the military under guidance set forth in military regulations. Despite an active preemployment screening program for all military pilots, the prevalence of occupational back pain in helicopter pilots ranges between 50% and 80% (10, 50, 53).

Most recommendations on physical fitness as a preventive modality stem from back rehabilitation programs that have demonstrated an improvement of back injury symptoms and a decrease in the recurrence of back pain in chronic back pain sufferers. Recent work evaluating the effect of a back exercise rehabilitation program on the sitting time of workers has demonstrated that it is possible to increase the pain-free sitting in workers who suffer from back pain due to excessive sitting (52). Although no data exist on exercise programs as a primary preventive measure for helicopter pilot back pain, researchers have nevertheless recommended a good exercise program as a preventive measure for helicopter pilots (46, 49, 50).

Conclusions

The low number of studies found in the this literature review limits the conclusions that can be formed. It is clear from the data that intense, graded, or moderate exercise programs can increase the endurance of back musculature. Other studies evaluating solely the ability of exercise to increase endurance of back muscles in pain-free subjects support this conclusion (24). The findings of these studies, when evaluated together, indicate that programs designed to increase back endurance have a positive influence on both subjective and objective measurements among individuals suffering from back pain.

Although the current study is not conclusive in its findings, when combined with other studies evaluating the effect of endurance training of the back muscles on the prevention of back pain, it does indicate that a back endurance program may be a viable way to prevent back pain in helicopter air crew. Currently there is not enough scientific data to support a recommendation for the use of a back endurance training program as a primary preventive measure for helicopter back pain.

Further studies on back endurance training and, its effect on preventing back pain in helicopter pilots, need to be performed prior to making a recommendation. A prospective interventional study evaluating back pain in helicopter pilots, and the effect of back endurance training program, would provide valuable information for this unique occupational group.

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